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Douglas-fir Dwarf Mistletoe Spread, Intensification, and Tree Growth Impact: Thirty-Eight Year Remeasurement

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INTRODUCTION

A study was established in 1970 to measure Douglas-fir dwarf mistletoe (*Arceuthobium douglasii* Engelm.) spread and intensification and dwarf mistletoe impact on Douglas-fir growth and mortality in four precommercially thinned treatments (Dooling 1970 and Dooling, et al. 1986). All plots are located near the South Fork of Lolo Creek, Lolo National Forest, Montana on a Douglas-fir/Ninebark (PSME/PHMA5) Habitat Type (Figure 1). The study was designed to help determine levels of dwarf-mistletoe removal through thinning and pruning that would reduce wood volume losses below an economic threshold and help understand the spread and intensification of Douglas-fir dwarf mistletoe in thinned stands (Dooling 1970).

METHODS

In 1970, one of four silvicultural treatments was applied to each plot with dwarf mistletoe treatments superimposed as subplots on each plot (Figure 1 and Table 1). Three replicates were originally proposed, but only two were installed for a total of eight plots or 24 subplots (four silvicultural treatments X three dwarf mistletoe treatments X two replicates). Because a check plot was inadvertently thinned, an additional silvicultural treatment plot (plot 25) was established.

Berg (1974) noted the original overstory was ponderosa pine, but he didn't describe the Douglas-fir component of the original stand. Steve Slaughter, Lolo National Forest Silviculturist, provided stand histories from FACTS (Forest Service Activity Tracking System) reports (Slaughter 2008). Some history prior to study establishment were provided for 15 of the 25 plots. No pre-1970 stand information was available for plots 1, 3, 7, 11, 12, 19, 20, 21, 22, and 25. Plots 10 and 18 were planted in 1947. Plots 2, 4, 5, 6, 8, 9, 23, and 24 were sanitized/salvaged in 1964 and a shelterwood cut was completed on plots 13, 14, 15, 16, and 17 in that same year. From 1971 through 1987 a variety of treatments (precommercial thin, sanitation/salvage,

Figure 1. Douglas-fir dwarf mistletoe plot distribution.

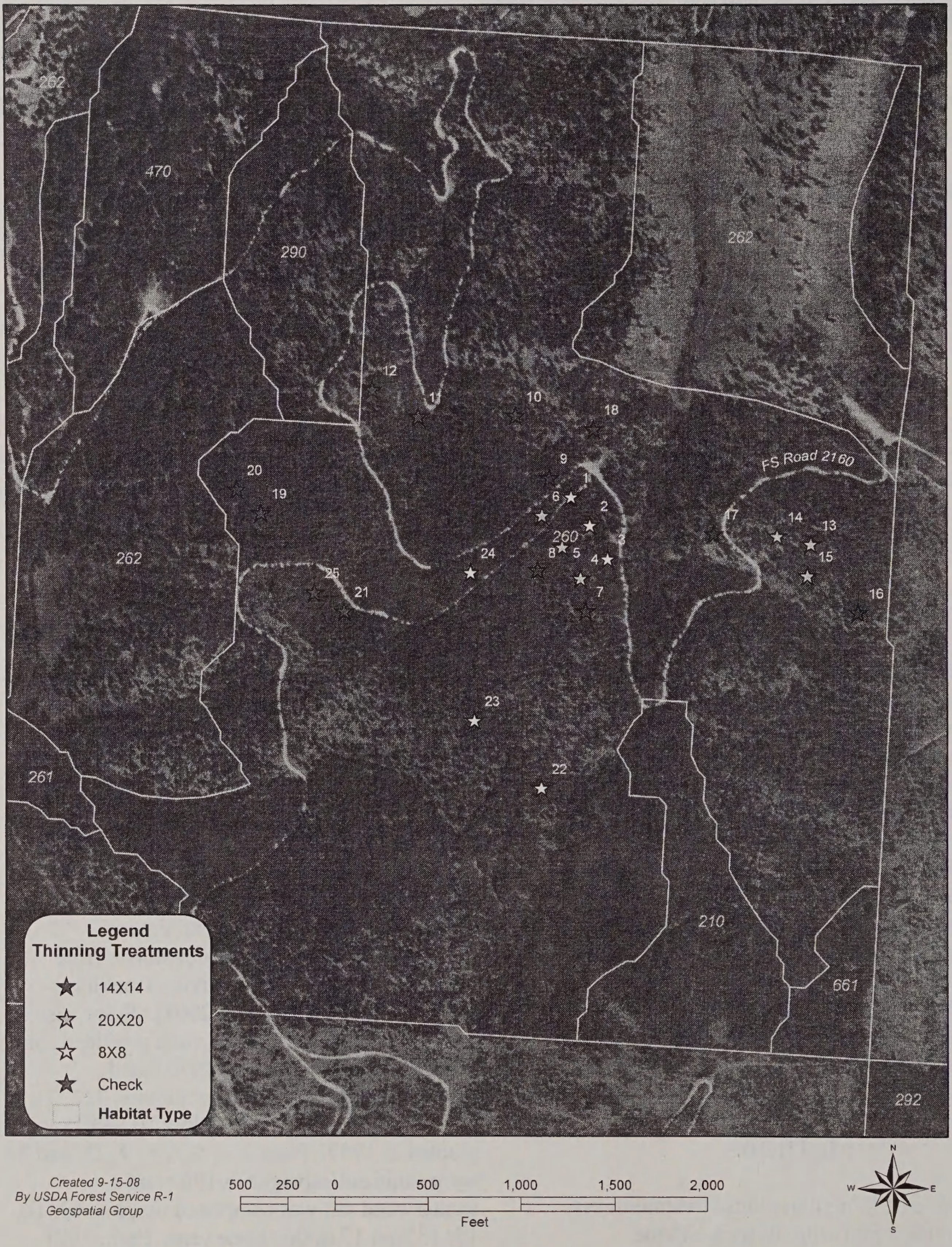

Table 1. Dwarf Mistletoe Infection Rates in Douglas-fir.[A]

Thin Trt.	DM Trt.	Plot No.	1970			1973			1978			1983			1988			2008		
			Live	Inf.	%	Live	Inf.	%	Live	Inf.	%	Live	Inf.	%	Live	Inf.	%	Live	Inf.	%
Check	Check	11	38	0	0	38	0	0	38	0	0	38	0	0	38	0	0	33	0	0
Check	Check	25[B]	45	25	55.6	45	28	62.2	44	35	79.5	44	38	86.4	44	40	90.9	33	27	81.8
Check	Low	10	27	0	0	27	0	0	27	0	0	27	0	0	27	0	0	26	0	0
Check	Low	21	43	0	0	43	1	2.3	43	1	2.3	42	1	2.4	42	2	4.8	39	0	0
Check	High	12	30	0	0	30	0	0	30	0	0	30	0	0	30	0	0	25	0	0
Check	High	19	47	0	0	47	0	0	47	1	2.1	47	7	14.9	45	5	11.1	37	4	10.8
Check	Total		185	0	**0**	185	1	**0.5**	185	2	**1.1**	184	8	**4.3**	182	7	**3.8**	160	4	**2.5**
8 X 8	Check	3	84	1	1.2	84	9	10.7	84	13	15.5	81	18	22.2	78	16	20.5	75	7	9.3
8 X 8	Check	23	85	1	1.2	85	5	5.9	85	5	5.9	85	6	7.1	85	6	7.1	85	3	3.5
8 X 8	Low	2	57	0	0	57	0	0	57	0	0	56	0	0	56	0	0	55	0	0
8 X 8	Low	24	99	6	6.1	99	10	10.1	99	18	18.2	98	24	24.5	98	31	31.6	97	26	26.8
8 X 8	High	1	70	0	0	70	0	0	70	1	1.4	55	1	1.8	51	2	3.9	50	2	4
8 X 8	High	22	90	0	0	90	0	0	90	1	1.1	90	1	1.1	90	1	1.1	86	2	2.3
8 X 8	Total		485	8	**1.6**	485	24	**4.9**	485	38	**7.8**	465	50	**10.8**	458	56	**12.2**	448	39	**8.7**
14X14	Check	8	32	1	3.1	32	1	3.1	32	2	6.3	32	2	6.3	32	3	9.4	31	1	3.2
14X14	Check	17	26	0	0	26	1	3.8	26	3	11.5	26	4	15.4	26	4	15.4	26	4	15.4
14X14	Check	20	39	6	15.4	39	9	23.1	39	10	25.6	38	10	26.3	31	8	25.8	31	11	35.5
14X14	Low	9	37	0	0	37	0	0	37	0	0	36	0	0	36	0	0	36	1	2.8
14X14	Low	16	37	0	0	37	0	0	37	0	0	36	0	0	36	0	0	32	0	0
14X14	High	7	20	0	0	20	0	0	20	3	15.0	20	4	20.0	20	4	20.0	20	1	5.0
14X14	High	18	27	0	0	27	0	0	27	0	0	24	0	0	24	0	0	22	0	0
14X14	Total		218	7	**3.2**	218	11	**5.0**	218	18	**8.3**	212	20	**9.4**	205	19	**9.3**	198	18	**9.1**
20X20	Check	6	16	0	0	16	0	0	16	0	0	14	0	0	14	0	0	14	0	0
20X20	Check	15	14	0	0	14	0	0	14	0	0	14	0	0	14	0	0	14	0	0
20X20	Low	4	12	1	3.8	12	0	0	12	0	0	12	0	0	12	1	8.3	11	1	9.1
20X20	Low	14	14	0	0	14	0	0	14	0	0	13	0	0	13	0	0	10	0	0
20X20	High	5	18	0	0	18	0	0	18	0	0	18	0	0	18	0	0	18	0	0
20X20	High	13	18	0	0	18	0	0	18	0	0	18	0	0	18	0	0	18	0	0
20X20	Total		92	1	**1.0**	92	0	**0**	92	0	**0**	89	0	**0**	89	1	**1.1**	85	1	**1.2**
All			980	16	**1.6**	980	36	**3.7**	980	58	**5.9**	950	78	**8.2**	934	83	**8.9**	891	62	**7.0**

[A]Only Douglas-fir dwarf mistletoe hosts (Douglas-fir) included.

[B]Plot 25 was not included in the 'Check' average or 'All' average since it is highly dissimilar to all other plots.

liberation cut, site preparation and planting) were variously applied to stands in which the plots are situated. Some of these treatments were apparently applied to the plots and/or plot buffers, while others didn't include the plots but only the stand area outside of the plots (Anonymous 1988).

TREATMENTS

Silvicultural Treatments. Each one-quarter acre plot was precommercially thinned to an 8 X 8, 14 X 14, or 20 X 20 foot spacing or left unthinned (check). With the exception of the check, only crop trees at appropriate spacing were retained on each plot and all other trees were removed in 1970. Crop trees were defined by Dooling (1970) as:

> Trees selected as potential crop trees should be dominants and codominants. The trees should be vigorous growing, free of other major diseases or deformities, and of good form. Trees with trunk swellings, burls, twin tops, malformed leaders, crooks, or showing evidence of mechanical injury will not be selected. Crop tree selection will conform with the practice of maintaining mixed stands of species suited to the site.

Crop trees included ponderosa pine in most plots and western larch and lodgepole pine in a few plots each; however, Douglas-fir was the primary crop tree species in all subplots. The project proposal (Dooling 1970) stated 100 trees would be identified and tagged as sample trees in the check (unthinned) plots. All crop trees in the thinned stands and sample trees in the check were tagged with wire or nails at breast height. Wired tags were nailed in subsequent years as trees reached adequate size.

Dwarf Mistletoe Treatments. Dwarf mistletoe treatments consisted of a check, partial-high control, and partial-low control. In the partial-high control subplots, no trees with a DMR (dwarf mistletoe rating) greater than one were retained. Some trees on partial-high control plots were pruned to reduce DMR rating to one if necessary to maintain stocking levels. Trees with DMRs up to three were retained on the partial-low control plots. No pruning was done on the partial-low control plots. No mistletoe was removed on the check subplots. Although the maximum levels of mistletoe allowed per subplot were established, there were no minimums; therefore, some of the subplots for each of the three dwarf mistletoe treatments could be free from dwarf mistletoe and indeed that was the case. See Table 1 for assignment of silvicultural and dwarf mistletoe treatments to plots.

One-quarter acre subplots were monumented at four corners with steel fence posts and buffered by a one-half chain (33 feet) strip that received the same treatment as the respective subplot. All treatments were completed in 1970. Since one of the silvicultural check plots was mistakenly thinned to 14 X 14 foot spacing, plot 25 was added as a substitute in 1971. However, a brief summary provided by a field crew member after taking data in plot 25 in 1988 stated that this plot "does not reflect the characteristics of the rest of the plots" (Anonymous 1988). Review of 1970 data and observations in 2008 support this conclusion. The trees in plot 25 were substantially larger and more heavily infected with dwarf mistletoe than those in other plots.

In May and June 2008, tree height, dbh, height to crown, live crown ratio, dwarf mistletoe rating (for each crown third) using the Hawksworth method, and crown class were recorded for each tagged tree on all 25 plots. In addition, a rapid assessment of Douglas-fir ingrowth was completed by tallying all trees less than nine feet in height. The ingrowth assessment was carried out to help determine if ingrowth (see below) provided by FVS (Forest Vegetation Simulator) was accurate.

Dwarf Mistletoe Rating (DMR). Dwarf mistletoe infections were measured on all tagged

trees in 1970, 1973, 1978, 1983, 1988, and 2008. At some point between the writings of the proposal (Dooling 1970) and the writing of the 1986 report (Dooling et al), the dwarf mistletoe rating system changed from a 6-point system used by Leaphart, Graham, and Wicker (no citation provided in proposal) to Hawksworth's 6-point dwarf mistletoe rating system (Hawksworth 1977). Hawksworth (1977) does not cite a previous 6-point system used by Leaphart, Graham, and Wicker as described in Dooling's proposal. The two systems are very similar; they both divide the crown of an infected tree into thirds, rate each third for dwarf mistletoe, and add up the thirds for tree ratings that could range from zero (no infection) to six (most severely infected). The difference between the two systems is the distinction between a rating of one or two in each third. Whereas the Leaphart, Graham, and Wicker system assigns a two when more than one-third of the branches are infected in a crown third, the Hawksworth system requires one-half or more of the branches to be infected to move a rating up from a one to a two. In 1998, all trees were rated using both systems. The project file from 1988 (Anonymous) noted the following:

> During this remeasurement, the question of changing the mistletoe rating system was explored. Using Hawksworth's method, that which is currently used by the [F]orest [S]ervice, was proposed to replace the 6 point system designed by Leaphart, Graham, and Wicker which has been used in previous measurements. Both systems were recorded on the data sheets...Many differences were noted between the old and the new systems. I feel that it would significantly change results if Hawksworth's method was used from now on. The old system is not hard to learn. If the system were changed now, all data previously collected on mistletoe could not be used in data analysis. The old rating system's numbers can not be assumed to reflect Hawksworth's rating.

A review of the 1988 data shows half of the twelve subplots that contained dwarf mistletoe had at least one tree with different ratings when the tree was rated using the original six-point system compared to the Hawksworth system. Since "each tree was rated for dwarf mistletoe infection using the 6-Class dwarf mistletoe rating (DMR) system (Hawksworth 1977)" (Dooling, et al. 1986) contradicts the 1988 project file, the dwarf mistletoe rating system used may have changed sometime between 1970 and 1983. The latter year is the last time data was taken under Dooling's oversight. Since we were unable to determine which system was used in 1970, 1973, 1978, and 1983, the only changes in dwarf mistletoe ratings we can compare with any confidence are between 1988 and 2008 using the Hawksworth system.

FVS Analyses. Data from nine plots were entered into FVS to determine if the model would accurately predict the spread and intensification of dwarf mistletoe on each of these plots with each of these treatments. The other sixteen plots were not used in the model for three reasons. First, twelve plots were removed because there was no dwarf mistletoe on those plots in 1988 (plots 2, 5, 6, 9, 10, 11, 12, 13, 14, 15, 16, 18). Three additional plots were not used because they were control thinning treatments (plots 19, 21, 25) without any way to determine plot density at the beginning of a model cycle. Finally, plot 1 was not included because too many trees were lost due to road widening and Christmas tree cutting. Since ingrowth was not measured any time before 2008, ingrowth was modeled from 1970 to 1990 and the modeled ingrowth was applied to the 1998 data. Ingrowth was modeled for twenty rather than eighteen years because the model's default is a 10 year cycle and it performs best on 10 year cycles (David 2005 and Keyser 2008). The ingrowth modeled from 1998 to 2008 was then compared to the rapid assessment of Douglas-fir ingrowth completed in 2008. Since a walk-through tally of ingrowth shows that ingrowth was overestimated by the model for all plots (data not shown), the model was run with

and without the ingrowth data with the assumption that the 2008 field collected dwarf mistletoe spread and intensification data should fall somewhere between the modeled data with ingrowth and the modeled data without ingrowth.

RESULTS AND DISCUSSION

Spread and Intensification. Thinning and pruning treatments done three and eight years after plot establishment confounded analysis of spread and intensification of dwarf mistletoe early in the study (Dooling et al. 1986). The project proposal (Dooling 1970) stated plots would be established and treated in 1970 and re-measured after three years followed by five year re-measurement intervals. However, it appears pruning and thinning treatments continued during the first two re-measurements. No thinning or pruning was done after 1978.

In 1988, 13 of the 25 plots contained dwarf mistletoe-infected Douglas-fir trees (Table 1) with all plots except 3, 24, and 25 containing less than ten infected trees. In 2008, one additional plot (plot 9) contained an individual infected tree and all plots except 20, 24, and 25 contained less than ten infected trees. In plot 3, 10 of the 16 infected trees in 1988 lost all live infections by 2008 and one tree not infected in 1988 was infected by 2008 resulting in a net loss of nine infected trees. Three of the dwarf mistletoe check plots (no dwarf mistletoe removed) contained no dwarf mistletoe and dwarf mistletoe levels across most plots remained very low during the 38-year period.

Percent infected Douglas-fir decreased in most of the infected plots (Table 1) over the last twenty years. Plot DMR increased in about half of the infected plots and decreased in half the infected plots, while plot DMI (dwarf mistletoe ratings averaged over infected trees only) was unchanged, increased, and decreased in about one-third of the infected plots each (Table 2). In plots where dwarf mistletoe decreased, some of the brooms were shaded out. Most of these dead brooms remained visible on the trees for the 2008 remeasurements. Many live brooms had several feet of shaded-out dead branches above them and some contained live dwarf-mistletoe shoots.

Very little within-tree dwarf mistletoe intensification occurred from 1988 to 2008, with a trend towards reduced DMRs for infected trees (Table 3). Over ninety percent of the trees remained within one DMR of the previous rating. The very low dwarf mistletoe spread and intensification in the study area may have been due to poor dwarf mistletoe seed production, poor seed viability, shading out of Douglas-fir branches, or a combination of these factors. Dooling et al (1986) attributed little spread and intensification differences between treatments in 1983 to young stand age and low dwarf mistletoe intensity. A primary reason for little spread and intensification within this stand is the lack of a Douglas-fir dwarf mistletoe infected overstory (Hadfield, et al. 2000).

A trend toward increasing DMR developed in the 14 X 14 thinning treatment from 1988 to 2008, while a trend toward decreasing DMR developed in the control and 8 X 8 treatment. The higher densities in the control and 8 X 8 treatments appeared to shade out dwarf mistletoe infected branches more effectively.

Growth and Yield. Given stand DMRs remained below a rating of one for all stands (except the dissimilar plot 25) and inadequate replication due to no dwarf mistletoe infections in some plots, growth and yield impacts on crop trees could not be expected. However, a trend towards reduced height growth after 38 years was apparent as DMR increased above a rating of 3 or 4 (Tables 4 and 5). This is consistent with other studies that have shown no reduced height and diameter growth in lightly infected Douglas-fir compared to uninfected Douglas-fir (Mallams 2007).

Table 2. Dwarf Mistletoe Ratings in Douglas-fir.

Thin Trt.	DM Trt.	Plot No.	1970		1973		1978		1983		1988		2008	
			DMR[A]	DMI[B]	DMR	DMI	DMR	DMI	DMR	DMI	DMR	DMI	DMR	DMI
Check	Check	11	0	0	0	0	0	0	0	0	0	0	0	0
Check	Check	25[C]	1.822	3.280	1.933	3.107	2.318	2.914	2.556	3.026	3.114	3.425	2.625	3.111
Check	Low	10	0	0	0	0	0	0	0	0	0	0	0	0
Check	Low	21	0	0	0.023	1	0.023	1	0.024	1	0.048	1	0	0
Check	High	12	0	0	0	0	0	0	0	0	0	0	0	0
Check	High	19	0	0	0	0	0.021	1	0.213	1.429	0.156	1.400	0.108	1
Check	Avg.		0	**0**	0.0	**1.000**	0.009	**1.000**	0.05	**1.215**	0.04	**1.200**	0.020	**1.000**
8 X 8	Check	3	0.012	1	0.119	1.111	0.167	1.077	0.272	1.222	0.244	1.188	0.107	1.143
8 X 8	Check	23	0.012	1	0.071	1.200	0.071	1.2	0.094	1.333	0.071	1	0.035	1
8 X 8	Low	2	0	0	0	0	0	0	0	0	0	0	0	0
8 X 8	Low	24	0.081	1.333	0.141	1.400	0.222	1.222	0.330	1.333	0.378	1.194	0.433	1.615
8 X 8	High	1	0	0	0	0	0.014	1	0.018	1	0.039	1	0.040	1
8 X 8	High	22	0	0	0	0	0.011	1	0.011	1	0.011	1	0.023	1
8 X 8	Avg.		0.018	**1.111**	0.055	**1.237**	0.081	**1.100**	0.121	**1.178**	0.124	**1.076**	0.103	**1.152**
14X14	Check	8	0.031	1	0.065	2	0.094	1.5	0.094	1.5	0.125	1.330	0.032	1
14X14	Check	17	0	0	0.038	1	0.115	1	0.160	1	0.154	1	0.269	1.75
14X14	Check	20	0.308	2	0.359	1.556	0.487	1.9	0.526	2	0.419	1.625	0.581	1.636
14X14	Low	9	0	0	0	0	0	0	0	0	0	0	0.028	1
14X14	Low	16	0	0	0	0	0	0	0	0	0	0	0	0
14X14	High	7	0	0	0	0	0.150	1	0.200	1	0.200	1	0.050	1
14X14	High	18	0	0	0	0	0	0	0	0	0	0	0	0
14X14	Avg.		0.048	**1.500**	0.066	**1.519**	0.121	**1.350**	0.140	**1.375**	0.128	**1.239**	0.137	**1.277**
20X20	Check	6	0	0	0	0	0	0	0	0	0	0	0	0
20X20	Check	15	0	0	0	0	0	0	0	0	0	0	0	0
20X20	Low	4	0.083	1	0	0	0	0	0	0	0.083	1	0.091	1
20X20	Low	14	0	0	0	0	0	0	0	0	0	0	0	0
20X20	High	5	0	0	0	0	0	0	0	0	0	0	0	0
20X20	High	13	0	0	0	0	0	0	0	0	0	0	0	0
20X20	Avg.		0.014	**1.000**	0	**0**	0	**0**	0	**0**	0.014	**1.000**	0.015	**1.000**
All	Avg.		0.022	**1.222**	0.034	**1.324**	0.057	**1.173**	0.081	**1.256**	0.080	**1.145**	0.075	**1.179**

[A]DMR = Average dwarf mistletoe rating of all Douglas-fir trees.
[B]DMI = Average dwarf mistletoe rating of only infected trees.
[C]Plot 25 was not included in the 'Check' average or 'All' average since it is highly dissimilar to all other plots.

Table 3. Within Tree Intensification of Dwarf Mistletoe in Douglas-fir from 1988 to 2008.

	Dwarf Mistletoe Rating (DMR) Increase or Decrease[A]					
Change in DMR	-2	-1	0	+1	+2	+3
Plot 25[B]	5	7	12	6	1	1
Check	1	4	2	1	0	0
8 X 8	1	27	22	11	3	1
14 X 14	0	7	6	10	0	0
Total	2	38	30	22	3	1

[A]Number of trees with changes in DMR.
[B]Plot 25 shown separate since plot characteristics are highly dissimilar from other plots.

Table 4. Growth Impacts from Douglas-fir Dwarf Mistletoe Infections.[A]

DMR	Number of Trees 1970[B]/1988/2008	1970 Tree Height (Feet)	1988 Tree Height (Feet)	2008 Tree Height (Feet)	1970 Tree DBH (Inches)	1988 Tree DBH (Inches)	2008 Tree DBH (Inches)
0	668/564/563	8.1	25.2	42.1	1.1	4.4	7.2
1	10/70/42	11.0	27.1	45.2	1.6	4.9	8.0
2	4/11/16	11.3	25.9	43.4	1.2	4.8	7.8
3	2/3/4	13.2	24.0	42.0	2.1	5.2	8.2
4	0/0/1	-	-	17.0	-	-	4.2
5	0/0/0	-	-	-	-	-	-
6	0/0/0	-	-	-	-	-	-
Total	684/648/626						

[A]Only trees from infested plots (1, 3, 4, 7, 8, 9, 17, 19, 20, 21, 22, 23, and 24) included. Average for all trees in DMR class.
[B]A total of 870 trees were identified for these plots, but other species and those lost to Christmas tree cutting between 1970 and 1973 were not included.

Table 5. Growth Impacts from Douglas-fir Dwarf Mistletoe Infections in Plot 25.

DMR	Number of Trees 1970/1988/2008	1970 Tree Height (Feet)	1988 Tree Height (Feet)	2008 Tree Height (Feet)	1970 Tree DBH (Inches)	1988 Tree DBH (Inches)	2008 Tree DBH (Inches)
0	20/4/5	19.2	24.7	32.0	3.4	3.4	5.7
1	1/4/5	25.0	24.5	43.2	4.0	4.1	8.1
2	6/9/6	22.3	34.1	42.2	3.2	6.2	7.7
3	6/9/6	24.3	29.9	40.5	4.2	4.8	8.1
4	10/6/5	25.8	28.7	37.2	4.8	5.6	7.9
5	1/8/1	26.0	29.0	29.0	4.6	5.9	6.4
6	1/4/4	26.6	17.3	26.0	5.7	4.8	7.6
Total	45/44/32						

Table 6. Forest Vegetation Simulator (FVS) Projection of Douglas-fir Dwarf Mistletoe Spread and Intensification Compared to Real Data.

		Percent Trees Infected				Plot DMR				Plot DMI			
		Real Data		2008 FVS Proj.		Real Data		2008 FVS Proj.		Real Data		2008 FVS Proj.	
Thin Treatment	Plot	1988	2008	Ingrowth	No Ingrowth	1988	2008	Ingrowth	No Ingrowth	1988	2008	Ingrowth	No Ingrowth
8 X 8	3	20.5	**9.3**	33	44	0.2	**0.1**	1.0	1.0	1.2	**1.1**	1.8	2.0
8 X 8	22	1.1	**2.3**	13	30	0.0	**0.0**	0.3	0.5	1.0	**1.0**	1.4	1.4
8 X 8	23	7.1	**3.5**	40	59	0.1	**0.0**	1.1	1.3	1.0	**1.0**	1.6	1.9
8 X 8	24	31.6	**26.8**	47	69	0.4	**0.4**	1.3	1.5	1.2	**1.6**	1.8	2.0
14 X 14	7	20.0	**5.0**	51	27	0.2	**0.1**	1.3	0.9	1.0	**1.0**	1.7	2.0
14 X 14	8	9.4	**3.2**	36	11	0.1	**0.0**	0.9	0.4	1.3	**1.0**	1.8	2.4
14 X 14	17	15.4	**15.4**	24	29	0.2	**0.3**	0.7	0.9	1.0	**1.8**	1.6	2.1
14 X 14	20	25.8	**35.5**	57	32	0.4	**0.6**	1.2	0.9	1.6	**1.6**	1.8	2.0
20 X 20	4	8.3	**9.1**	51	32	0.1	**0.1**	1.1	1.0	1.0	**1.0**	1.6	1.5

Mortality. Mortality that occurred during the last twenty years was observed in seven of twelve non-infected plots and nine of thirteen infected plots. This was an overall increase compared to previous years (Table 1), except for mortality caused by road widening and Christmas tree cutting in the early years of the study. Although most recent mortality in 24 plots was attributable to competition from adjacent trees and some root disease, half of the twelve dead trees in plot 25 had DMRs of 5 or 6 and four of the twelve had DMRs of 3 or 4 in 1988. Unlike the other 24 plots, dwarf mistletoe probably contributed to most of the tree mortality in plot 25.

FVS Analyses. Results of FVS analyses are shown in Table 6. Except for DMI on plot 17 and percent infected on plot 20, all FVS projections were high compared to true spread and intensification of the Douglas-fir dwarf mistletoe on these plots.

While FVS projected an increase in dwarf mistletoe spread (percent infected) on all plots with or without projected regeneration, this was not the case with real data (Table 6). Only one plot (plot 20) showed an increase similar to that projected by FVS while five plots showed a reduction in live dwarf mistletoe infections, one was equal, and two plots showed slight increases.

Although projected infection rates did not reflect true infection rates, the differences between projections with ingrowth and those without ingrowth are logical. All the 8 X 8 thinning treatments showed a greater projected spread without ingrowth added than with ingrowth; whereas, all the 14 X 14 (except plot 17) and 20 X 20 treatments showed the opposite with greater spread with ingrowth added. With the higher density stands in the 8 X 8 thinnings, there is a greater potential for shading-out dwarf mistletoe infected branches and small trees compared to 14 X 14 and 20 X 20 thinnings. Plot 17 is different from the other 14 X 14 plots in that fifty-eight percent of the projected ingrowth was Douglas-fir and in plots 7, 8, and 20 seventy-two percent of the projected ingrowth was Douglas-fir; therefore, a greater ingrowth infection rate in plots 7, 8, and 20 might be expected.
Although plot DMR was projected to increase substantially on all plots, it decreased on four plots, was unchanged on three plots, and increased slightly on two plots (plots 17 and 20). All real DMRs were much lower than projected by FVS.

Plot DMI was projected to increase in all plots with or without ingrowth added; however, two plots decreased in DMI, five plots were unchanged, and two plots increased in DMI between 1988 and 2008. For plot 22, projected DMI was the same with or without ingrowth added. Projected DMI was higher without ingrowth added than with ingrowth on all other plots except the 20 X 20 plot. True DMI on plot 17 was between projected DMI with ingrowth and without ingrowth added and true DMI on plots 20 and 24 neared projected DMI with ingrowth added. As with percent infected, DMI was projected to be higher without ingrowth than with ingrowth in the 8 X 8 thinnings, but higher with ingrowth in the 14 X 14 and 20 X 20 thinnings, except for plot 17. Again, this can be explained by the shading-out effect described for spread projections described above.

CONCLUSION

The original objectives to determine levels of dwarf-mistletoe removal through thinning and pruning to reduce wood volume losses below an economic threshold; and, comparing spread and intensification of Douglas-fir dwarf mistletoe across thinning treatments could not be met due to several factors negatively influencing the long-term value of these plots. These factors include (1) only two replicates originally installed, (2) trees lost due to road widening and Christmas tree cutting, (3) undocumented change in dwarf mistletoe rating system, (4) lack of ingrowth data, and (5) lack of dwarf mistletoe in

about half of the plots. Although permanent plot data is extremely valuable in understanding dwarf mistletoe spread, intensification, and impact on host trees, the factors above lead to the conclusion that limited resources should not be used in future measurements of these plots as originally intended. In other words, this project should be discontinued. With that said, there is worthwhile information to be salvaged from data collected from these plots and value in maintaining a few of the subplots.

Although the original intent of these plots is lost, some of the plots could be measured in the future for inclusion in the PTIPS (Pest Trend-Impact Plot System) program which is used for model validation/calibration; a need highlighted by the differences observed between FVS projections and real spread and intensification of dwarf mistletoe in these plots over the last 20 years. Any plots with infected trees may be helpful in calibrating the dwarf mistletoe impact model. Many of these plots may provide insight into spread and intensification of Douglas-fir dwarf mistletoe at very low levels in stands. Since only seven plots (3, 17, 19, 20, 23, 24, and 25) currently have more than one or two infected trees, these would be the logical plots to consider for inclusion in the PTIPS program. In addition to data already collected, future data should include ingrowth measurements to better clarify long-term spread, intensification, and impact of Douglas-fir dwarf mistletoe in these plots.

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LITERATURE CITED

Anonymous. 1988. Project File.

Berg, D. 1974. Unpublished letter.

David, L. 2005. Dwarf Mistletoe Impact Modeling System User Guide and Reference Manual Nonspatial Model 2005 Update. Unpublished Report. Forest Health Technology Enterprise Team, USDA Forest Service. Fort Collins, Colorado. 73p.

Dooling, O. J. 1970. Administrative Study: Study plan for the establishment of a dwarf mistletoe growth impact, associated mortality, and spread and intensification study in infected stands of Douglas-fir, lodgepole pine, and western larch. Unpublished document. Division of State and Private Forestry, USDA Forest Service. Missoula, Montana. 10p.

Dooling, O. J., Johnson, R. R., and Eder, R.G. 1986. Growth impact, spread, and intensification of dwarf mistletoe in Douglas-fir and lodgepole pine in Montana. FPM Report 86-6. USDA Forest Service Northern Region, Forest Pest Management, Missoula, Montana. 11p.

Hadfield, J. S., Mathiasen, R. L., and Hawksworth, F. G. 2000. Douglas-fir dwarf mistletoe. Forest Insect and Disease Leaflet 54. USDA Forest Service. 9p.

Hawksworth, F. G. 1977. The 6-class dwarf mistletoe rating system. General Technical Report RM-48. USDA Forest Service Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado. 7p.

Keyser, C. E. 2008. Personal communication.

Mallams, K. M. 2007. Permanent plots for measuring spread and impact of Douglas-fir dwarf mistletoe in the Southern Oregon Cascades, Pacific Northwest Region. SWOFIDSC-07-04. USDA Forest Service Pacific Northwest Region, Southwest Oregon Forest Insect and Disease Service Center, Central Point, Oregon. 34p.

Slaughter, S. 2008. Personal communication.